# Multi-tool hole drilling with sequence dependent drilling times


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Hole drilling is one of the fundamental machining processes used in the manufacturing of durable goods. Drilling a set of holes on a simple two dimensional work piece using a single tool can be modeled as a Traveling Salesman Problem (TSP). However, hole drilling typically involves work pieces that require holes to be drilled of different diameters. In many cases, a single tool is assigned beforehand to every hole. This so-called multi-tool hole problem also reduces to the TSP if only a single tool is used to complete a hole. Many effective algorithms for TSPs exist and it is surprising to the authors that still many papers are being published on this basic hole drilling application. However, as pointed out by Dewil et al. [1], there remain quite some research questions on multi-tool hole drilling with precedence constraints and on multi-tool hole drilling with sequence dependent drilling times. Multi-tool hole drilling with precedence constraints can be modeled as the precedence constrained TSP and fast optimization approaches suited for the problem sizes typically encountered in hole drilling have recently been proposed [2].

However, multi-tool hole drilling application with sequence dependent drilling times as first presented by Kolahan and Liang [3] is much more complex. Only a limited number of papers tackled this problem and do not exploit the problem structure at all [4][5] and no linear MIP formulation has been proposed.

We present two exact linear MIP formulations based on modeling the problem as a Precedence Constrained Generalized Traveling Salesman Problem. In addition, we identify several quick-win improvements in the original tabu search algorithm presented by Kolahan & Liang. Firstly, two preprocessing rules can greatly reduce the problem size in some instances. Secondly, Kolahan & Liang apparently used a very computationally expensive implementation of a tabu list. We implement a more efficient approach based on a hash function. Thirdly, for a problem with $n$ holes and $m$ tools, the original approach required an O(n) operation to evaluate the objective function value of a single neighbor. By using a slightly different solution representation, this can be reduced to an O(m) evaluation.

## References


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